



Medical Research Council :
Committee on Traumatic Shock
and on Blood Transfusion

THE TREATMENT OF WOUND SHOCK

(Instructions produced in co-operation with
the Army Medical Service)

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THE TREATMENT OF WOUND SHOCK.

MECHANISM OF WOUND SHOCK

The results of injury are complex and, in dealing with the wounded, the treatment of shock must supplement the arrest of hæmorrhage, prevention of infection and repair of damaged tissue. Shock may occur with any injury but particularly with those that are accompanied by hæmorrhage and widespread tissue damage.

By **primary shock** is meant a condition of collapse which may follow soon after the receipt of injury and which is not due to hæmorrhage. The condition resembles fainting and responds to the recumbent position, warmth, relief of pain and administration of stimulants. The rest of this memorandum deals with secondary shock and primary shock will not be considered further.

Secondary or wound shock develops insidiously some hours after injury. It is characterised by weakness, pallor and raised pulse rate, and in advanced cases by lowered body temperature, sweating, low blood-pressure, rapid "thready" pulse, vomiting, and intense thirst. It is to be emphasised that medical officers should train themselves to recognise wound shock in its earliest stages, for it is in these that treatment is likely to prove effective.

Wound shock closely resembles the effects of hæmorrhage in its clinical features and is likewise a condition of circulatory failure, due to diminished blood volume, with a consequent fall in heart output and blood-flow through the tissues of the body. External hæmorrhage, and loss of blood and blood plasma into the tissues, account for the decrease in blood-volume in wound shock. Whereas hæmorrhage is a relatively simple disturbance, shock is known to be a state resulting from many factors in addition to blood loss; fatigue, dehydration, pain and exposure to cold and wet may in individual cases all contribute to its origin. If shock is to be successfully prevented or treated, these contributory factors all demand attention, and, in some instances, no further measures are required. In the majority of cases, however, active steps must be taken to restore blood volume.

Some figures from the war of 1914-18 will indicate the relationship between the clinical condition and blood volume. The cases of shock were divided into three groups. Group I comprised patients whose clinical condition was good; pulse rate between 90 and 110, systolic pressure above 95 mm. Hg and blood volume over 75 per cent. of normal. In Group II the general condition was serious; pulse rate 120-140, systolic pressure 70-90 mm. Hg and blood volume between 65 and 75 per cent. of normal. In Group III the patient was dangerously ill; pulse rate 120-160, systolic pressure 60 mm. Hg or less, and the blood volume between 50 and 65 per cent. of normal. These findings, which are in essential agreement with others obtained at the same time and subsequently, show that a reduction of the blood volume by 25 per cent. produces only slight symptomatic disturbance in the patient, whereas a further reduction of 25 per cent. produces a condition so serious that recovery is rare.

The lesson of these figures is clear. If measures to restore the blood volume are to prove effective, every effort should be made to apply them early, before the blood pressure has fallen below 90 mm. Hg or the pulse rate has risen above 120. Moreover, the amount of blood, plasma, or serum transfused should be large enough to overcome the deficit; at least 2 pints of blood are required in mild cases, and 4 pints of blood in severe cases*, for the normal blood volume is about 9 pints. To delay transfusion until signs of advanced shock have appeared is to wait until irreversible damage has occurred to blood vessels and central nervous system and no permanent restoration of the circulation can be achieved.

* In practice, it may be found that the same volume of citrate plasma or a smaller volume of serum may be equally effective.

Observers during the war of 1914–1918, as well as experimental investigators since, have found that a constant feature of shock is **reduction of blood volume**. All the distressing and dangerous symptoms as well as the progressive deterioration in general condition, which is characteristic of shock and which, unless arrested, terminates fatally because of circulatory failure, can be largely explained by this one feature. Treatment of shock based on this hypothesis is eminently successful.

General Effect of Reduction in Blood Volume

Reduction in blood volume causes a general vasoconstriction which attempts to maintain the blood pressure at a normal level. The vasoconstriction may be completely effective for a volume loss of approximately two pints (1136 cc.) but when the loss is greater the blood pressure cannot be maintained and the systolic pressure may, in extreme cases, fall even lower than 50 mm. Hg. Thus, when reduction in blood volume is large and the cardiac output is poor, both the vasoconstriction and the lowered blood pressure cause diminution in the tissue circulation, and, if inadequate tissue circulation is too long continued, the oxygen lack causes irreparable damage. One manifestation of this permanent damage is an increase in capillary permeability so that generalised capillary leakage, including pulmonary oedema, occurs. Consequently, when blood is introduced into the circulation, the plasma cannot be retained. Then, the patient is unable to recover even if his blood volume be fully restored with blood itself.

Condition of the Circulation in Shock.

In theory, the condition of the circulation depends upon whether the reduction in blood volume is due to hæmorrhage or to plasma loss. Both causes operate in almost every case of war injury.

(a) *Simple hæmorrhage*.—With simple acute hæmorrhage all elements of the blood are lost. Until the physiological compensatory mechanism begins to come into action, the blood count shows no significant change and gives no indication of the amount of blood lost. The compensatory mechanism is an absorption of tissue fluid which restores the blood volume. Some evidence of compensatory blood dilution may be detected within an hour. The process, however, may not be complete for a considerable time. The mechanism is inefficient and slow if the tissues are depleted of fluid, dehydrated subjects (and wounded men are usually in this state) having but little tissue fluid to yield up for the purpose. Most wounded men tolerate hæmorrhage badly, and the need to restore blood volume is correspondingly urgent.

(b) *Plasma loss*.—Diminution in blood volume caused by plasma loss is more dangerous than the same reduction due to hæmorrhage. Loss of plasma results in a concentration of the cellular elements of the blood which increases the viscosity. The increased viscosity of the blood causes a reduction in tissue circulation over and above that produced by vasoconstriction and fall of blood pressure, and so still further embarrasses the circulation. Under these conditions the patient suffers from oxygen lack.

(c) *Combined hæmorrhage and plasma loss*.—Theoretically, blood dilution or blood concentration should arise according as to whether simple hæmorrhage or plasma loss is the more marked feature; dilution might, indeed, balance concentration, so that, apart from a determination of blood volume, there would be no apparent gross changes in the composition of the blood. From the practical aspect and with the wounds of war, the usual dehydration of a wounded man tends to inhibit compensatory blood dilution for hæmorrhage, while the amount of tissue injury encourages plasma loss.

CLINICAL RECOGNITION OF WOUND SHOCK

The recognition of shock in its advanced stages presents no difficulties. As previously pointed out, the condition is characterised by weakness, pallor, raised

pulse rate, low body temperature, sweating, low blood pressure, rapid "thready" pulse, vomiting, and intense thirst; the lips, ears and nails may be cyanosed and the tongue dry; consciousness may be impaired but it is important to realise that many even moribund patients are mentally alert.

Recognition of shock in the earlier stages is by no means easy. Difficulties arise because pallor and increased pulse rate, which are the only constant manifestations of early shock, are not confined to this condition. Shock should be suspected in every case where injury has been extensive, where much blood has been lost and exposure very prolonged, and where the skin is pale and cold and the pulse over 100. These cases should be watched carefully. Some improve, the colour of the skin becomes more normal and the pulse rate slows. In others definite signs of shock develop. Indications that shock is developing or progressing are a rising pulse rate, a decrease in pulse pressure (difference between systolic and diastolic values), increasing pallor and the onset of sweating. In the later stages of shock the systolic blood pressure may fall to 50 mm. Hg or less.

If signs of shock are present, particularly pallor and a pulse rate above 110, treatment should be instituted without delay, even though the systolic blood pressure is over 100 mm. Hg. If the blood pressure is over 100 mm. Hg, the condition is partially compensated but the arterial pressure is being maintained only by intense vasoconstriction and is liable to fall rapidly with the slightest intensification of the shock, as for example, from anæsthesia or a small loss of blood or plasma.

TREATMENT

General Principles

Ideally, the treatment of shock "should begin before its onset", for he who awaits the fully developed clinical picture with marked circulatory disturbance and the blood pressure at a dangerously low level, will seldom treat a case successfully. The good clinician will recognise not only the definitely established condition but also the prodromal features which may be expected to precede shock or which may mask symptoms and signs. In every case an estimate should be made as soon as possible as to how many of the factors which contribute to shock are operating. The various measures required should then be instituted promptly in an order appropriate for the patient. *It is now generally accepted that the most important single requirement for arresting the progressive deterioration in general condition which is such a feature of shock, is restoration of blood volume and thereby of tissue metabolism.* It cannot be emphasised too often that success depends mainly upon the promptness with which this restoration can be made. Restoration of blood volume should precede operative measures in all cases except those in which the nature of the injury brooks no surgical delay.

Treatment before reaching military Casualty Clearing Station or civilian Casualty Receiving Hospital

The treatment that can be given in the advanced medical units, Regimental Aid Posts, Advanced and Main Dressing Stations, Field Ambulances, or at civilian First Aid Posts, is dependent upon military operations or enemy action at the time. During quiescent periods it should be possible to transfuse casualties in the Fighting Services with plasma at an Advanced Dressing Station, while at the Main Dressing Station it should be possible to form a Resuscitation Centre and to undertake some of the details of treatment, including administration of oxygen (p. 7).

Control of Hæmorrhage

During active operations the most that can be done in very advanced positions is to limit hæmorrhage and plasma loss efficiently, with either a firm bandage or tourniquet (p. 5), and to contrive some comfortable form of splint in order to prevent the pain and local plasma loss caused by movement of a fractured limb

during transport. When a limb is so mangled that there is obviously no chance of repair, a tourniquet should be applied close to the upper level of the wound in order to cut off the whole blood supply to the wounded area and so prevent not only loss of blood but also loss of plasma into the injured tissue.

Protection from Cold.

The wounded must be protected from cold. Stretcher-bearers should be familiar with the proper use of waterproof sheets and blankets as described in R.A.M.C. Training Manual (1935) Sections 74 and 75. When blankets are not available, protective clothing should be placed between the canvas of the stretcher and the patient, rather than on top of the patient. While the patient is awaiting evacuation the foot end of the stretcher should be raised.

Administration of Water.

It is of great importance to administer water freely and repeatedly to all wounded except those who are unconscious or who have abdominal wounds. It is an advantage if the water contains half a teaspoonful of salt to the pint. Warm drinks such as sweetened tea should be used when possible.

Blood Transfusion.

The Army transfusion apparatus allows of blood or plasma being administered at least as far forward as Main Dressing Stations. The further forward that this life-saving treatment can be given, the greater the chance of success.

Morphine.

All casualties who have had morphine administered should have the amount and time of administration written on their foreheads or recorded on a label attached to them, in order that they may not be overdosed on arriving at the C.C.S. or Casualty Receiving Hospital.

Chest Wounds.

Open wounds of the chest, unless quickly closed, cause a high mortality. Medical officers in forward areas should therefore be prepared to close such wounds immediately, even though nothing more than skin sutures be used.

Treatment at military C.C.S. or civilian Casualty Receiving Hospital

A patient admitted to a C.C.S. or Casualty Receiving Hospital, who is judged by the medical officer in the *Receiving Room* to be unfit for immediate operation by reason of shock, should be admitted to a special Resuscitation Ward where the essential rest and quiet, so impossible to obtain in a busy general surgical ward, can be ensured, and where other measures designed to restore the circulation can be quietly carried out.

As soon as the patient is admitted to the *Resuscitation Ward* the medical officer should decide as to the urgency of operation. The more pressing cases should remain on stretchers, in order to avoid undue disturbance before removal to the operating theatre; less severe cases should be put into a warm bed in the ordinary manner. All beds and stretchers should be slanted head downwards by raising the foot nine inches.

As a general rule, no attempt is made in a Resuscitation Ward to carry out local treatment to the injury except for obvious requirements such as the arrest of free hæmorrhage or the adjustment of a splint on a painful improperly immobilised limb. Apart from such simple procedures, treatment for collapse and shock as detailed below must always take precedence over reparative surgery. There must be occasional exceptions to this rule, as when, through delay, infection is well developed, or when, because of the site of wounding, no delay in local treatment is admissible. In such cases simultaneous general and local treatment will offer the only chance of success.

In a Resuscitation Ward the following features which cause or contribute to shock need to be considered and dealt with:—(1) FATIGUE, (2) COLD, (3) PAIN AND RESTLESSNESS, (4) HÆMORRHAGE AND PLASMA LOSS, (5) REDUCTION OF BLOOD VOLUME, (6) DEHYDRATION, (7) OXYGEN LACK, (8) INFECTION, (9) SPECIAL INJURIES.

Treatment of Fatigue and Cold.

At a C.C.S. or Casualty Receiving Hospital efficient arrangements to combat fatigue and cold should be available. Wounded men become exhausted from pain, lack of sleep, fear, and prolonged exertions previous to wounding. Shocked patients, therefore, require complete rest at the earliest opportunity, under conditions of quiet and shelter. Wet and dirty clothes must be cut off with as little disturbance as possible. The patient should be clothed in warm pyjamas and placed in a bed warmed by hot water bottles, or by hot bricks wrapped in blankets or by more elaborate apparatus, such as an electric blanket, a radiant heat bath, or a shock cage. Arrangements must be made for the warming of stretcher cases while they are awaiting attention.

Relief of Pain and Restlessness.

Morphine.—For the relief of pain, which is of the first importance, morphine is of great and exceptional value; it is also useful to allay undue restlessness. It can be given by mouth, or by subcutaneous, intramuscular or intravenous injection. Usually it is given subcutaneously or intramuscularly in a dose of $\frac{1}{4}$ – $\frac{1}{2}$ grain of a salt (e.g. hydrochloride or tartrate) of morphine. It may be given orally (either allowed to dissolve under the tongue or swallowed) in similar doses, but the analgesic effect then takes longer to develop. When the circulation is very feeble, absorption from the stomach or subcutaneous tissues may be abnormally slow. An almost immediate effect of morphine can be obtained, regardless of the state of the circulation, by intravenous injection. Up to $\frac{1}{4}$ grain may be administered intravenously; the morphine should be diluted with sterile water to at least 1 c.c. and the solution injected slowly (the injection occupying at least one minute).

If a full dose of morphine, as above, has been given, a second dose should not be administered until at least four hours later. Excessive doses may increase the symptoms of shock. If there are signs of serious depression of the respiratory centre due to morphine overdosage, oxygen should be administered.

Arrest of Hæmorrhage and Plasma Loss.

A casualty admitted to a Resuscitation Ward needs to have the site of wounding superficially examined in order to confirm that hæmorrhage has been arrested and to ascertain if a tourniquet has been used. Whether the tourniquet is removed or left in position depends very much on the extent of the injury. When a limb is so severely mangled that conservation is unlikely and the tourniquet is found to be in a satisfactory position just above the site of the injury, it must be left in position until amputation above is performed later. Removal of the tourniquet is inadvisable, because extensive plasma loss quickly occurs into the injured area, even though there is no bleeding. If removal of the tourniquet is unavoidable, arrangements for a transfusion should be made.

When a limb is not hopelessly damaged, the blood supply must not be completely occluded. Instead of a tight tourniquet, it is better to use large strong bandages bound tightly over several layers of wool, and so to apply firm diffuse pressure not only over the wound but also embracing the whole limb. Such bandaging effectively limits plasma loss. Rubber bandages are apt to cause too much ischæmia and should not be used. Plasma loss in injured tissue is greatly increased by movement. Immobilisation is, therefore, of great importance.

Restoration of Blood Volume.

Experience during the war of 1914–1918 showed that the most valuable single method of combating shock was by transfusion of blood. This restores effective blood volume and increases oxygen carrying power. The earlier the blood volume

is restored, the better the prognosis. When blood volume has been so reduced that arterial pressure is significantly decreased, consistently good results cannot be expected from the transfusion of one pint (568 cc.) which, owing to limitation in supply, was all that it was usually possible to administer to any one case at the time of the war of 1914–1918. The establishment of a Blood Transfusion Service aims at allowing an ample supply of blood to be available for each case, while the apparatus issued is designed to make rapid transfusion possible under almost any conditions (see Appendices A and B). From two to four, or even more, of the pint bottles supplied by the Blood Transfusion Service may be required for a single case, according to severity.

Once the symptoms of shock have been relieved by transfusion, every effort should be made to limit the loss of blood at a subsequent operation. Symptoms of shock readily recur after even a small blood loss, and a volume of blood equal to that lost may not then again restore the patient. If hæmorrhage at operation is likely to occur, a drip transfusion should be set up at the beginning of the operation, in order immediately to compensate for any blood loss (see Appendix C).

Substances used for restoring Blood Volume.

(a) *Whole blood*.—This is of proved value for shock, irrespective of whether the symptoms are due to loss of blood by hæmorrhage or to local plasma loss. It has already been emphasised that the average case requires a much larger amount than is commonly used.

(b) *Human plasma, human serum*.—These substances, because of superior keeping qualities, are more convenient than whole blood for use under field conditions. In some cases, such as extensive burns, where reduction in blood volume is due entirely to plasma loss, replacement by plasma or serum is theoretically correct. Moreover, even in hæmorrhage, the restoration of blood volume, serum proteins and an adequate blood pressure may be of greater value than increasing the oxygen carrying power of the blood: indeed, when the amount of fluid in effective circulation is increased, the efficiency of such red cells as have not been lost by hæmorrhage is automatically increased.

(c) *Isotonic saline or glucose, Ringer-Locke solution, gum saline (see Appendix F)*.—If neither blood nor plasma nor serum is available, any of the above solutions can be given, *i.e.*, one pint of isotonic saline together with a pint of isotonic glucose may be administered in 15–30 minutes. Restoration of blood volume by the intravenous infusion of these solutions is of transient value only and is not devoid of risk (see below). Gum saline, unless very carefully prepared, has been found to be dangerous and it will not be issued for use in the field.

Dehydration.

Dehydration seriously contributes to shock. All wounded subjects can be assumed to be suffering from some degree of body water depletion. Since the loss of water by the body is accompanied by loss of salts, of which the most important is sodium chloride, all drinks should contain half a teaspoonful of salt to the pint. All casualties, except those who are unconscious or who are suffering from abdominal wounds, should be pressed to drink repeatedly and copiously even though there is vomiting from excess of morphine or other cause. Special orderlies or nurses should be detailed to encourage and assist patients to drink. Any delivery device which allows water to be swallowed with a minimum of effort and movement is of value. Warm sweetened tea or coffee should be given whenever possible and this, as with all drinks, should contain half a teaspoonful of salt to the pint. If necessary the rectal route may be used to supplement oral administration: warm, half normal (0.45 per cent.) sodium chloride (approximately $\frac{1}{2}$ teaspoonful per pint) is the most suitable fluid for rectal injection and should be given in amounts up to one pint.

Intravenous saline therapy in cases of shock is not without danger, and has to be employed with great care and judgment. The intravenous route should be used

only when oral and rectal administration are inadequate. The danger of intravenous administration of saline or glucose saline in cases of shock, when the plasma proteins have been depleted by hæmorrhage or local plasma loss, is due to the fact that the normal amount of water cannot be retained in the circulation, on account of the reduction in plasma protein. Hence there is a risk of pulmonary œdema. The intravenous administration of saline or glucose to a case of shock should, whenever possible, be preceded by a transfusion of whole blood or plasma. A pint of 5 per cent. glucose should be given, mixed or alternated with every pint of saline (see Appendix F). A certain amount of sodium chloride is necessary in order to retain fluid, but excess causes œdema. The rate of administration of saline or glucose should be slow. A drip infusion at the rate of 40 drops to the minute supplies a pint in four hours, and is suitable for the average case. If dehydration is severe or abnormal losses of water (especially vomiting) are occurring, the rate must be increased.

Administration of Oxygen.

Administration of oxygen in high concentration tends to relieve tissue anoxia and may bring about considerable improvement in a case of shock. Oxygen should be administered to all who manifest cyanosis of the lips, ears or nails. It is especially required when there is, in addition to shock, any interference with respiratory oxygen intake, such as occurs with wounds of the chest and airway, and with pulmonary œdema whether from gassing or from the grave circulatory failure found in shock itself. Furthermore, persons who have been involved in explosions in enclosed places frequently suffer from carbon monoxide poisoning, and they also require oxygen which should, in this case, contain 5 to 7 per cent. of carbon dioxide to bring about deeper breathing.

To administer high concentrations of oxygen the B.L.B. inhalation apparatus or a similar apparatus should be used (see Appendix E). For short administration a nitrous oxide bag and mask are useful, and even a Service respirator can be adapted. Oxygen and carbon dioxide can also be administered by means of a catheter or nasal tubes.

Infection.

Casualties who have been unable to receive speedy treatment may arrive with infection of wounds fully developed, and with lacerated devitalised tissue already necrotic and gangrenous. In such cases the absorption of the toxic products of bacterial infection causes a lowering of the patient's vitality which aggravates shock, and this contributes to the deterioration in the general condition. Infected tissue should be promptly removed by débridement, drainage or even amputation, and chemotherapeutic and other treatment designed to limit the infection should be given. In these circumstances resuscitation prior to operation is necessarily less satisfactory than in the case of injuries where delay in operating can be safely practised.

Special Injuries.

Certain injuries themselves cause a reduction in blood pressure. This aggravates any lowering due to shock itself. Injuries of this type include certain head wounds, spinal injuries which cause widespread vasomotor paralysis, and chest wounds, especially hæmopericardium and pneumothorax. The importance of immediate closure of open wounds of the thorax has already been emphasised.

Burns.

The principles of treatment are the same as for wound shock. Morphine is injected to relieve pain; the patient is kept warm and fluids are given by mouth. Before local treatment of the burn itself is begun, the blood pressure should be restored to a normal level by intravenous administration of citrated plasma, serum or whole blood.

Anæsthesia.

To induce anæsthesia, gas and oxygen, combined with ether if necessary, is the anæsthetic mixture of choice, provided that a skilled anæsthetist with the necessary apparatus is available; otherwise ether alone should be used. Care must be taken to see that cyanosis is not allowed to develop. Chloroform or spinal anæsthesia should not be employed. It must be emphasised that the administration of an anæsthetic to a shocked patient requires special care.

APPENDIX A

THE ARMY BLOOD TRANSFUSION OUTFITS AND INSTRUCTIONS

(1) Instructions for Using the Overseas Pattern of Transfusion Equipment for the Administration of Blood or Plasm

The equipment consists of blood (Universal Donor), or of plasma, in a pint bottle to which is attached, by a rubber band, a tin box containing the sterilised apparatus for administration (see diagram opposite).

Blood

The blood should be thoroughly mixed by inverting and rotating the bottle. The metal cap is then released and the temperature of the blood raised by standing the bottle in water at 40° C. (104° F.) for about 15 minutes. It is important to release the metal cap first, otherwise the bottle may break. Open the tin box and unwrap the cellophane packet. Plunge the short piercing tube A through one of the holes in the bung and follow with the long piercing tube B through the other hole. Fix the air inlet C to the base of the bottle with the rubber band, invert the bottle and hang it up by means of the wire handle. The blood may then be observed flowing through the filter D and the drip counter E; as soon as it appears at the wrapped end of the tubing, close screw clamp F. Slight pressure through air inlet C (which contains a non-return valve) may be necessary to start the flow of blood or to dislodge the soft jellylike clot which inevitably develops in stored blood. Two small packets G are attached near the end of the rubber tubing. One packet contains a sterile needle protected by a glass tube together with an adapter to fit the Army pattern syringe; the other contains a stainless steel cannula for cases in which it is necessary to cut down on a vein. Attach the needle to a syringe by means of the adapter and prove entry into the vein. Remove the syringe and adapter, leaving the needle in the vein, and attach the tubing to the needle. Unscrew clamp F and allow the blood to flow into the vein.

Approximately 15 minutes is required to empty the bottle, using the needle supplied, and the full head of 4 ft. provided. If necessary, pressure may be applied through the air inlet C either by blowing down it or with a Higginson's syringe.

Each crate of ten bottles is labelled with the date beyond which it is unwise to use the blood. When the supernatant plasma is tinged red, the blood should not be used.

A record of the success or otherwise of the transfusion should be entered on the numbered card enclosed in each box, and the card posted. This information is essential for the regulation of future supplies.

All used equipment should be returned to the officer in charge of the refrigerator unit issuing the blood.

Citrate Plasma

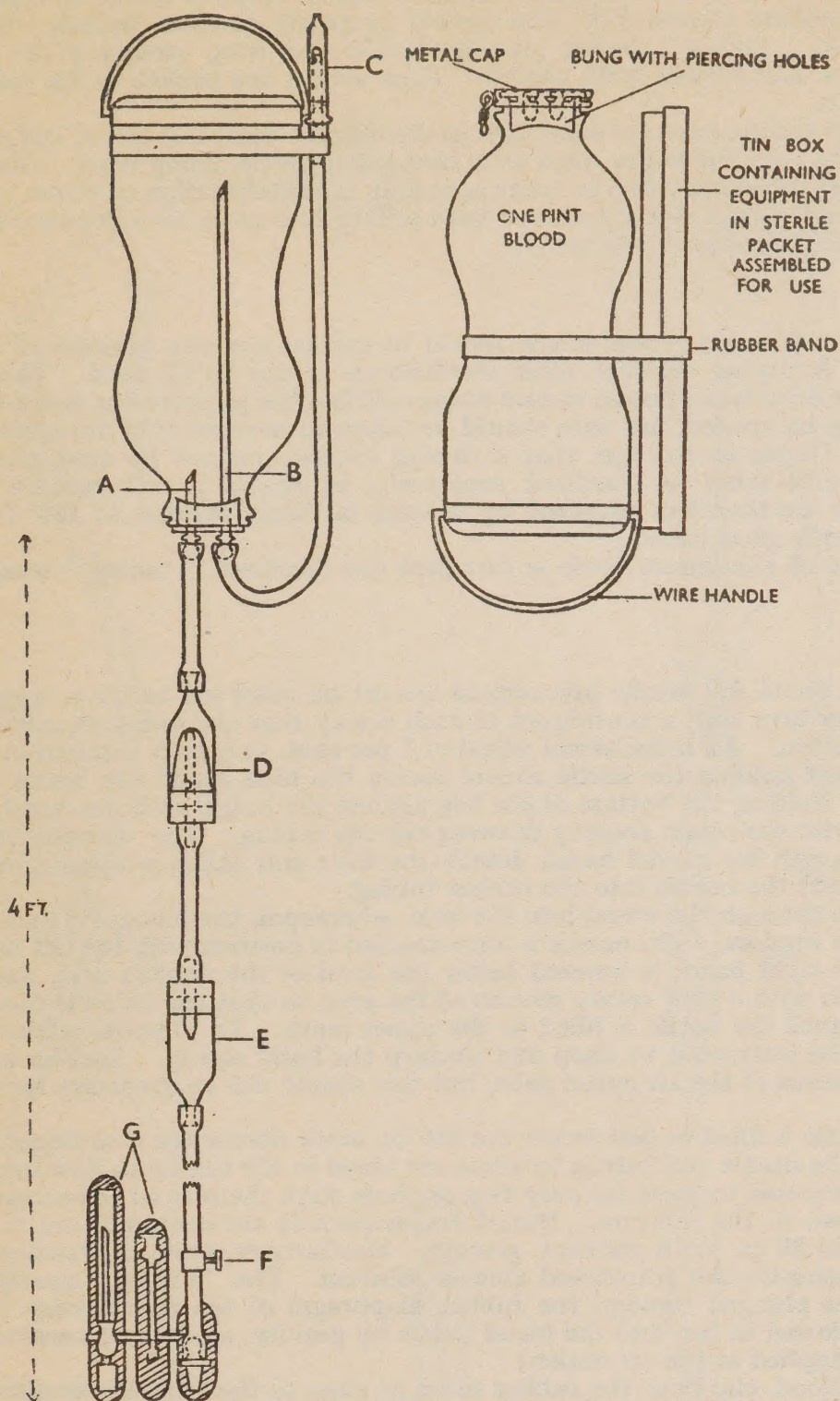
Plasma is an excellent substitute for blood in cases of hæmorrhage and shock. It should be administered in the same way as blood. Plasma should be stored in a cool, dark place. It is not necessary to place it in a refrigerator.

Plasma is apt to contain clots; these are removed by the mantle filter. The presence of a clot does not render a bottle unsuitable for use. If the clot is very large, the bottle should be shaken before use, in order to prevent blockage of the exit needle.

Bottles of plasma which are uniformly turbid before shaking should not be used, as they are probably contaminated with bacteria.

(2) Blood Transfusion Equipment for the Taking, Storing and Giving of Blood in Military Hospitals

The equipment consists of a moulded glass bottle (capacity 580 cc. or approximately 1 pint) fitted at the base with a wire handle, and two calico packets containing the requisite bungs and tubing. The "giving" packet is complete with needle, but the "taking" needle is supplied separately, for reasons stated below. With a first issue, the "taking" set and bottle are sometimes supplied fully assembled and ready for use.



**EQUIPMENT
ASSEMBLED FOR USE**

- A SHORT PIERCING TUBE
- B LONG PIERCING TUBE
- C AIR INLET CONTAINING NON-RETURN VALVE ENABLING PRESSURE TO BE APPLIED
- D MANTLE FILTER
- E DRIP COUNTER
- F SCREW CLIP
- G TWO PACKETS; ONE CONTAINING NEEDLE AND SYRINGE ADAPTOR, THE OTHER A CANNULA

Overseas pattern of Army transfusion equipment.

Preparation of the Apparatus for Taking

Take the bottle and rinse out with fresh distilled water. Run in 100 cc. of 3 per cent. sodium citrate solution (sodium citrate B.P. and freshly prepared distilled water). Insert the bung projecting from the "taking" packet into the bottle and wrap around it the piece of calico provided, tying top and bottom with thread. Then attach the packet to the side of the bottle with a rubber band.

It is important to autoclave the same day, in the manner described below, but once autoclaved the bottles may be kept for a few days in a cool place before being used. Glucose in a final concentration of approximately 0.5 per cent. assists in the preservation of blood. But, as glucose tends to caramelize if mixed and autoclaved with citrate, it is more convenient to add the glucose at the time of taking the blood (see below).

Sterilization

Sterilization of the taking equipment should be carried out at a pressure of 15 lb. of steam for 20 minutes. A drying vacuum after sterilization is not to be used. The steam should be shut off and the autoclave allowed to cool down. When the pressure has fallen to atmospheric, the autoclave may be opened, but care should be taken to prevent cold draughts from reaching the hot bottles. Owing to the fact that a drying vacuum cannot be used after sterilization, the "taking" needle must be sterilized separately, otherwise it will become blocked. The "taking" needles are therefore sterilized by heating in liquid paraffin to 150° C. and are then placed in small sterile glass tubes.

With an issue of equipment there is provided one sterilized "taking" needle in tube for each set.

Taking Blood

When taking blood full sterile precautions should be observed as for a surgical operation. Constrict the upper arm with a tourniquet in such a way that the veins are obstructed but the radial pulse unaffected. An intradermal wheal of 1 per cent. novocain is raised over the selected vein. The assistant holding the bottle should loosen the tape round the bottle and round the neck of the bag. Holding the bottom of the bag against the bottle with one hand, he should pull out the red tape with the other, thereby drawing out the tubing. The operator may now grasp the sterile tubing with his gloved hand, detach the tape and calico wrapping from the end of the tubing and insert the needle into the rubber tubing.

Pass the needle through the wheal into the vein, whereupon the blood will enter the tube and appear in the glass window. The needle is now steadied in position with the left hand, while the bottle, held in the right hand, is lowered below the level of the donor's arm, and the contents continuously mixed with a slow rotary motion of the arm, so that the blood is thoroughly mixed with the citrate, until the bottle is filled to the upper mark. To promote a free flow of blood, the donor should be instructed to clasp and unclasp the hand slowly. Suction may be applied to the bottle by means of the air outlet tube, but this should not be necessary except with small veins.

When the bottle is filled to just below the 540 cc. mark release the tourniquet, withdraw the needle, and raise the needle and tubing to allow the blood in the tubing to flow into the bottle.

(When it is proposed to store for only two or three days there is no advantage to be gained from adding glucose to the mixture. But if longer periods are contemplated it is convenient at this point to add 20 cc. of 15 per cent. glucose. MacCartney screw cap bottles are especially suitable as containers for the autoclaved glucose solution. The "taking" needle of the transfusion apparatus is plunged through the rubber diaphragm of the MacCartney bottle and the glucose solution allowed to run into the blood bottle by gravity, assisted, if necessary, by a little negative pressure applied at the air outlet.)

After taking blood, clip both the rubber tubes as close to the bung as possible and then cut off each piece of tubing close to the clip.

Storage

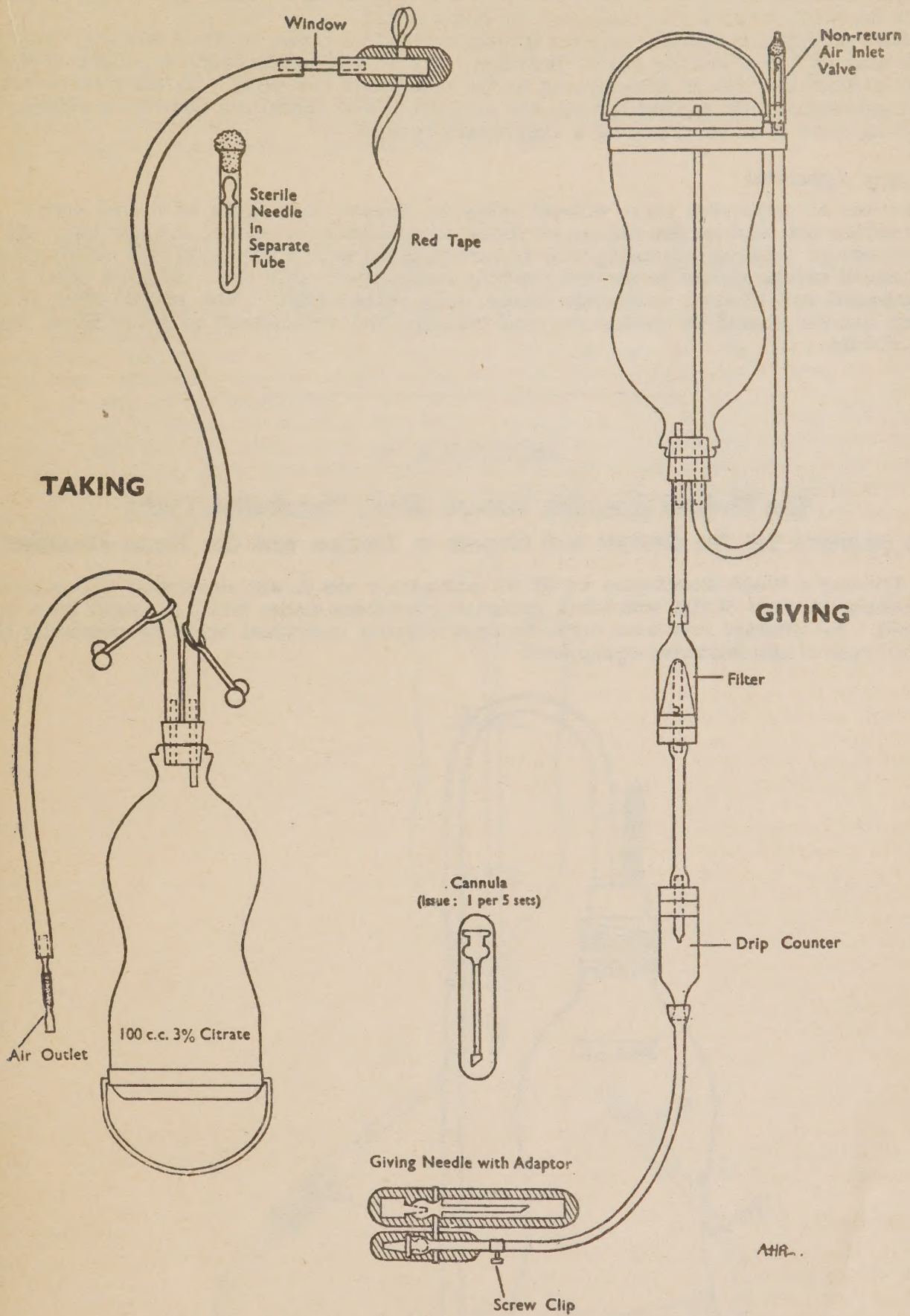
Place at once in a refrigerator and maintain between 2° C. and 6° C. Never allow the blood to freeze. The blood may be stored under these conditions for from 10-14 days, but it should be used as soon as possible. This equipment is unsuitable for transit.

To Prepare the Bottle for Giving

Sterilize the "giving" packets as for surgical dressings. Remove the calico wrapping from the neck of the bottle, carefully withdraw the used bung with its attachments, and insert the bung which has been removed from the "giving" packet, taking all sterile precautions. The tubing attachments and the needle may be rewrapped in the piece of calico and clipped to the side of the bottle with a rubber band. The bottle should be allowed to reach room temperature before use and may be carefully warmed in water at about 40° C. (104° F.) in urgent cases.

Giving Blood

Unwrap the attachments, remove the calico wrapping from the needle tubing mount, and clip the air inlet to the base of the bottle by a rubber band. Mix the blood by gently rotating the bottle. Invert the bottle and allow the blood to flow down through the filter and the long



Army transfusion equipment for use in military hospitals.

tubing until it appears at needle tubing mount, whereupon the tubing is clipped at its lower end by means of the screw clip.

Attach the needle (which is wrapped in a small packet and tied to the end of the tubing) to a small record syringe and insert into the selected vein. (An adapter is supplied with the needle to fit the Service pattern syringes.) When the needle is in the vein, remove the syringe and adapter and attach the rubber tube by means of the needle tubing mount. Release the clip and observe whether the blood is flowing by watching the drip counter.

Under ordinary conditions it requires approximately 15 minutes to give a bottle of blood with the full head of 4 feet and the needle provided. But in profoundly shocked patients it is often difficult to start the flow of blood owing to the collapse of the veins. In these circumstances positive pressure can be applied through the air inlet (which contains a non-return valve), either by blowing down it or by attaching a Higginson's syringe.

Cleaning of Apparatus

After use all apparatus must without delay be cleaned thoroughly with cold water. The rubber tubing cut off from the taking set should immediately be washed through with cold and then hot water; thorough cleansing may be accomplished with a wire 0.22 rifle cleaning brush. Other rubber tubing should be treated similarly immediately after use. All glass tubes should be dismantled and cleaned separately before being reassembled. The mantle filter in tube and drip counter should be washed out and returned for replacement to Army Blood Supply Depot, Bristol.

APPENDIX B

The Medical Research Council Blood Transfusion Outfit

(as provided for the Sectors and Depots in London and the Home Counties)

In devising a blood transfusion outfit for emergency use it was recognised that simplicity was essential in view of the somewhat primitive conditions under which it might have to be employed. An attempt has been made to meet varying individual needs by providing three different types of administering equipment.

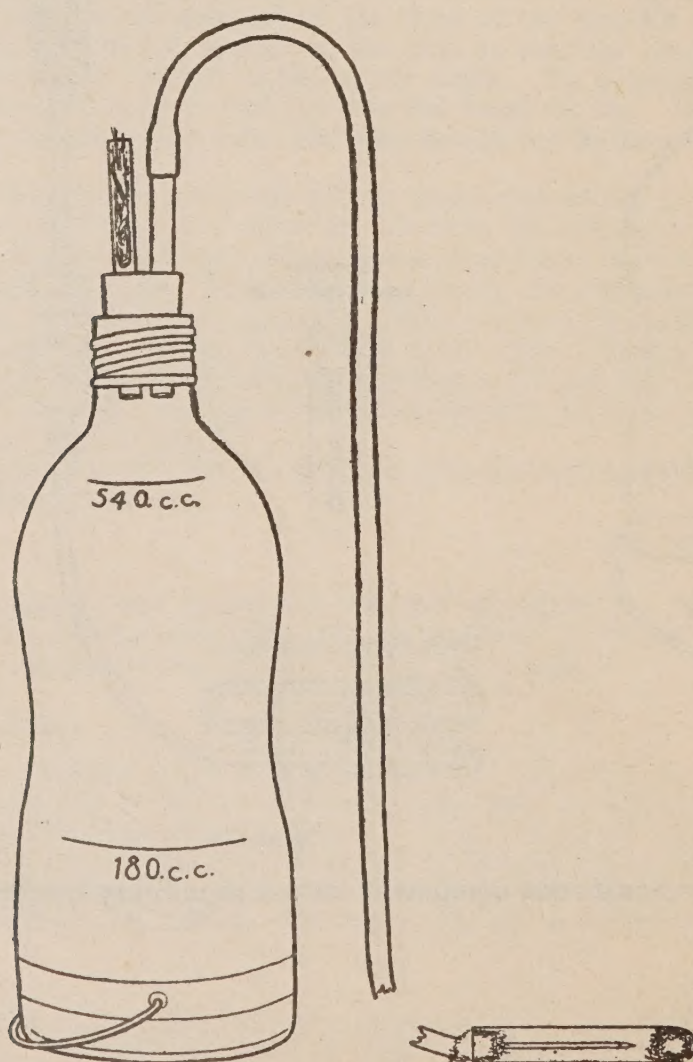


FIG. 1. Outfit for taking blood.

The bottle for the taking, storing and giving of blood is a modified pint milk bottle, slightly waisted to facilitate holding, fitted with an aluminium screw cap lined with a 4 mm. rubber diaphragm, and provided with a metal band and loop at the base for hanging the bottle in the inverted position when it is required to administer blood by gravity. Fig. 1 shows the bottle with the screw cap removed and replaced by a rubber bung and glass tubing.

Anticoagulant.—The anticoagulant solution consists of 100 cc. of 3 per cent. sodium citrate in distilled water to which is added 20 cc. of 15 per cent. glucose in distilled water. The citrate and glucose must be of a high grade of purity and the distilled water must be filtered and autoclaved immediately after distillation. Glucose tends to caramelize during autoclaving in the presence of citrate; it is therefore necessary to sterilize the citrate and glucose solutions separately and to mix after sterilisation. 120 cc. of anticoagulant solution is used* for 420 cc. of blood, making a total volume of 540 cc. (approximately 1 pint).

Withdrawal of Blood

The screw cap is removed and kept sterile. The bottle is then fitted with a rubber bung pierced by two three-inch glass tubes, one of which is lightly plugged with cotton-wool and acts as an air-vent. To the other is attached a length of rubber tubing and a stainless steel needle (Fig. 1) which is protected, after sterilization or during transport, by a small glass test tube. A sphygmomanometer cuff or tourniquet is applied to the upper arm of the donor, the skin over the vein cleaned and anæsthetized, and the needle inserted into the vein. The blood having been withdrawn and the rubber bung removed, the bottle is again sealed by the screw cap. If gravity proves insufficient to maintain a flow of blood, suction may be applied to the air-vent tube by means either of a Higginson's syringe or of a simple suction device. It is essential to mix the blood and anticoagulant by gentle rotation throughout the time of collection.

If the aluminium cap of the bottle is perforated, the rubber diaphragm inside being left intact, the bottle may be used for the vacuum method of taking blood. For this method the smaller-bored needle, ordinarily used for giving blood, should be inserted into the donor's vein.

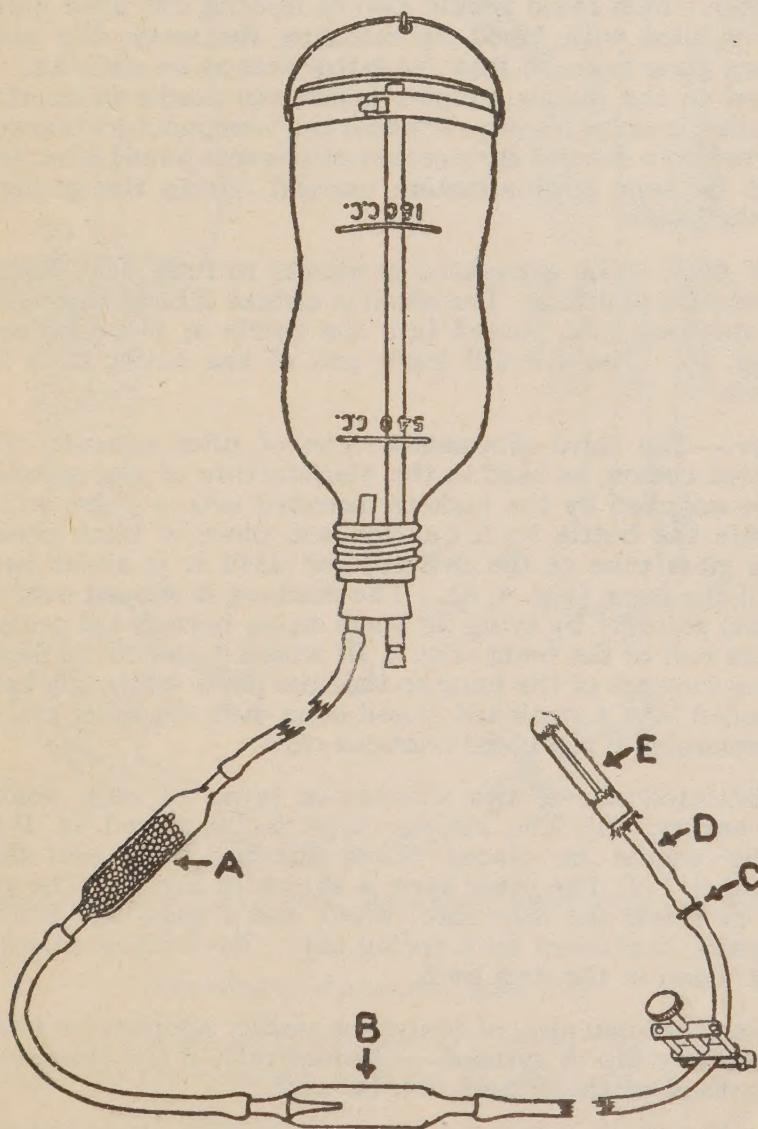


Fig. 2. Outfit for giving blood (with closed glass-bead filter and drip feed bulb).

* The bottle is marked at 180 cc. and 540 cc. The volume of anticoagulant originally used was 180 cc., but this has now been changed. The mark at 180 cc. is thus no longer relevant.

Storage of Blood

Blood should be stored at a steady temperature between 2° and 6° C. It must on no account be allowed to freeze. It should be noted that the temperature often varies widely in different parts of a refrigerator.

Administration of Blood

Temperature.—Blood must be warmed before it is given to patients. This should be done by standing the bottle in a large bowl of water at 40° C. (104° F.)—but at no higher temperature—for about 15 minutes and rotating it gently at intervals.

Apparatus.—Three alternative sets of component parts are now available, the main variant being the type of filter used. Two types of drip feed, described subsequently, can readily be added to these administering outfits.

1. *Closed glass-bead filter.*—This equipment (Fig. 2) consists of a rubber bung pierced by two glass tubes, one of which is long enough (9½ in.) to reach almost to the bottom of the bottle and is closed externally by a small cork. The other tube (2½ in.) has attached to its outer end, in sequence, a length of rubber tubing, an elongated glass bulb containing glass beads (Fig. 2, A), a further length of rubber tubing ending with a male metal adapter (C), a female adapter with a Record fitting attached to a short piece (1 to 1½ in.) of rubber tubing (D), and a narrow-bore stainless steel needle protected by a small test tube (E).

A screw pressure clip or a spring clip may be used. Fig. 2 also shows a simple type of drip feed bulb (B), included between the filter and the rubber tubing attached to the male adapter. To administer the blood by gravity it is necessary to replace the screw cap on the bottle by the rubber bung and invert the bottle. The two adapters should be separated, and the needle, attached to the short piece of rubber tubing and the female adapter, is passed into the vein. If the vein is entered blood appears through the end of the female adapter; this can then be joined to the male adapter, from which blood should also be flowing, the filter bulb and delivery tubing having been completely filled with blood by releasing the screw clip and then removing the small cork from the long glass tube, so that the latter acts as an air inlet. (If desired, a Record syringe can be attached to the female adapter before the needle is inserted into the vein, and suction can thus be applied in order to judge whether the venepuncture is successful; alternatively, the needle can be inserted on a Record syringe and afterwards joined directly to the male adapter.) The filter bulb should be kept approximately vertical during the giving of blood, to ensure effective filtration by the beads.

2. *Loose glass-bead filter.*—The apparatus is similar to that just described, except that the bulb containing glass beads is omitted. The blood is instead filtered through 25 cc. of glass beads, which are separately sterilized and poured into the bottle of blood immediately before fitting the delivery bung (Fig. 3). The fish-tail inner end of the outlet tube in the bung prevents obstruction by the beads.

3. *Gas mantle filter.*—The third alternative type of filter consists of an open cylindrical stocking of finely knitted cotton, as used in the manufacture of gas mantles. It is three and a half inches long, and is supplied by the makers threaded with a purse string at each end. The filter is supported inside the bottle by a quarter-inch piece of thick pressure tubing which is pushed on to the long glass tube of the delivery set until it is about two and a half inches from the narrow end of the bung (Fig. 4, A). The stocking is slipped over the bung and the long tube, one end is fastened securely by tying its purse string beyond the pressure tubing, the other is fitted round the inner end of the bung (Fig. 4, B) where it should be fixed by fine copper wire (Fig. 4, D), or by ridging the neck of the bung so that the purse string can be tied tightly. In this way the stocking is pulled into a stretched closed cone over the inner end of the delivery tube. This type of filter is preferable if the blood contains clots.

Drip feeds.—As indicated above, two alternative types of drip feed bulb are provided for the administering outfits. (1) The simpler type is illustrated in Fig. 2 (B). When this is used the screw clip should be placed below the drip bulb, near the needle, in order to obtain satisfactory control. (2) The other type is shown in Fig. 3. The screw clip in this case may be placed above or below the drip bulb, which has a glass side-piece with a short piece of rubber tubing attached, controlled by a spring clip. By suitable manipulation the operator can adjust the level of blood in the drip bulb.

The equipment as supplied can also, of course, be readily adapted for use with a simple funnel or with any form of two-way tap or syringe. Alternatively, if the aluminium cap is perforated, the "three-needle" method of transfusion can be used.

Citrate Plasma

To administer citrate plasma the same method should be followed as in the case of blood. Any of the above forms of filter may be used.

Practical Points in Using the Administering Outfits

(I) After any of the administering outfits has been properly assembled, the needle with its adapter should be disconnected and the screw clip temporarily opened to test for a free flow of blood through the apparatus. A free flow may be prevented by (a) contact of the inlet tube with the bottom of the bottle (a slight withdrawal of the tube will correct this); (b) obliteration of the lumen of the rubber tube due to perishing (the lumen can usually be restored by squeezing the rubber tube); (c) failure to remove the small cork from the air entry tube after the bottle has been inverted.

(II) The spring clip on the side arm of the drip feed cannot be autoclaved in the correct position as this would damage the rubber. It must be adjusted before the bottle is inverted. If it is not firmly closed, bubbles will form in the drip bulb.

(III) If more than one bottle of blood is given, the same gas mantle filter may be used again, provided the flow is free. To change the bottle, compress the tubing above the drip feed, remove the bung from the old bottle and insert into the new bottle. In the case of the closed glass-bead filter the tubing must be compressed above the filter before changing the cork.

(IV) If the filter clogs it is not necessary to change the needle. The tube can be compressed between the needle and the adapter while the filter is changed.

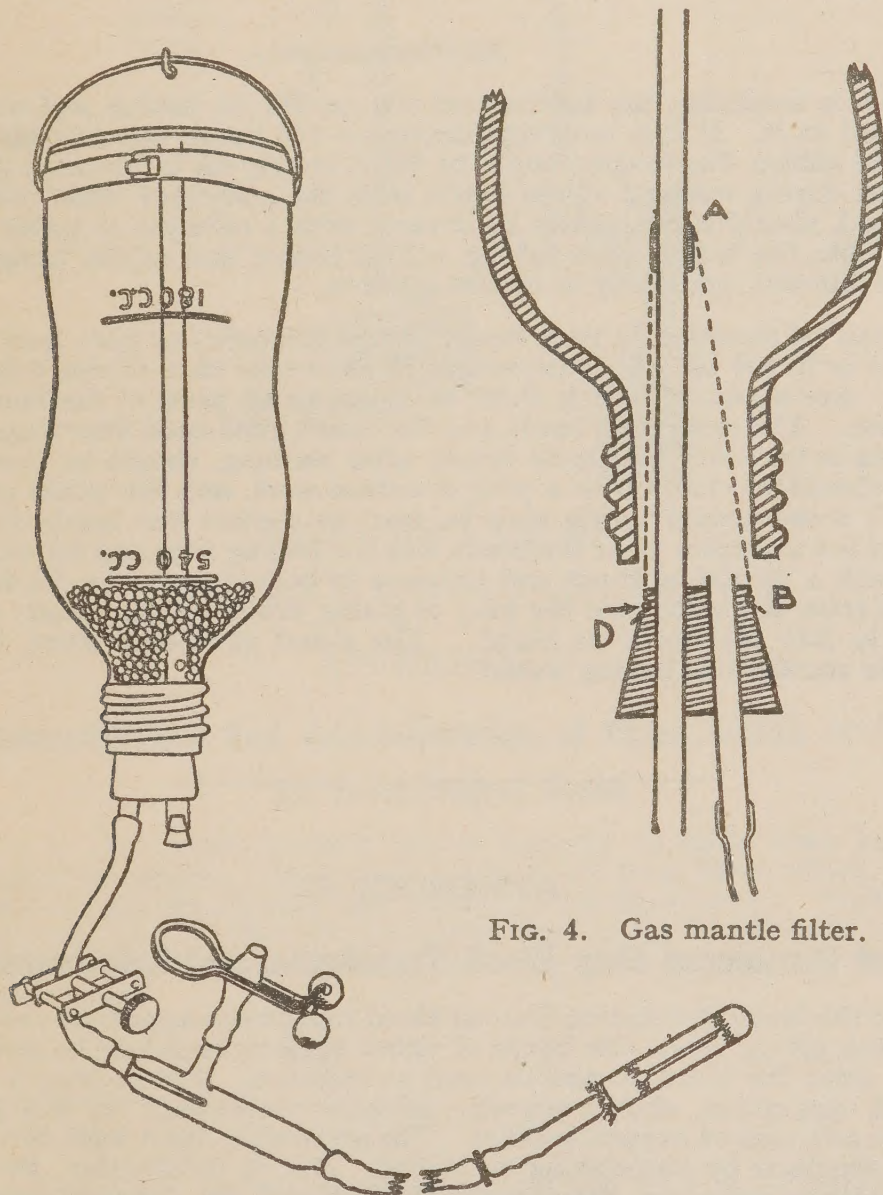


FIG. 4. Gas mantle filter.

Fig. 3. Outfit for giving blood (with loose glass-bead filter and drip feed bulb).

Cleaning of Apparatus after Use

ALL APPARATUS MUST BE RINSED OUT IMMEDIATELY AFTER USE, PREFERABLY WITH A WEAK SODA SOLUTION, AND CLEANED THOROUGHLY AS SOON AS POSSIBLE.

Bottles.—Wash in soapy water, then in plenty of tap water, drain and dry.

Glass tubing and rubber bungs.—Wash in hot soapy water, then in plenty of tap water, and dry. Unless washed immediately after use, glass tubing will need to be boiled in soapy water. It should then be washed with tap water, and dried.

Rubber tubing.—A stiff wire carrying a swab or narrow elongated brush (for example, a 0.22 rifle barrel cleaner) should be passed throughout the length of rubber tubing, since mere washing under the tap is insufficient to remove small adherent pieces of clot. Rubber tubing freshly obtained from the manufacturers *must* be washed to remove the French chalk with which its inside is coated.

Beads.—Immediately after use the bottle still containing the beads should be rinsed with tap water and then half-filled with soapy water. The bottle should be shaken vigorously, when the beads will scour the bottle and each other. This procedure should be repeated with two changes of tap water.

The closed glass-bead filter can be cleaned by washing through with a steady stream of water.

The gas mantle filter gauze cannot be cleaned and must be thrown away after use.

Needles.—The needles must be washed through with tap water, cleaned thoroughly with a stilette and sharpened if necessary.

N.B.—All glassware should be rinsed with *distilled* water, if possible; this however, may prove impracticable under emergency conditions.

Sterilisation

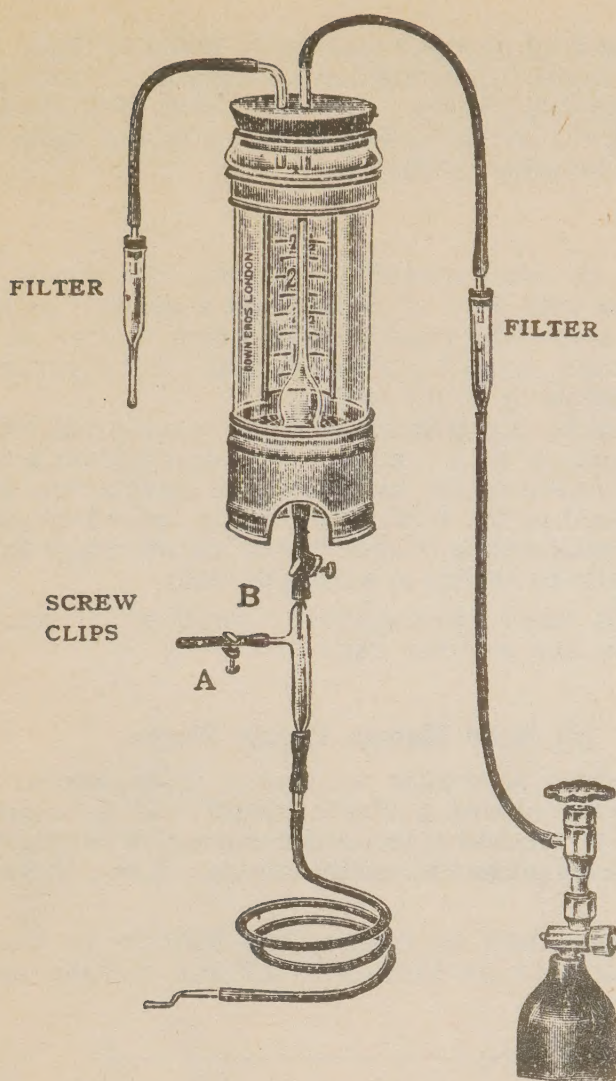
If an autoclave is available, the bottles and the outfits for taking and administering blood should be sterilised in it. If it is not proposed to use the bottle immediately for taking blood, the metal cap and rubber diaphragm should be fitted loosely on to the neck during autoclaving and screwed tight during removal of the bottle from the autoclave when cold; the metal cap and the bottle neck should subsequently be covered with a cellulose or paper cap. If an autoclave is not available, the bottle, glass tubing, rubber tubing and rubber bungs can be sterilised by boiling for 20 minutes, preferably in citrate solution.

The needles can be sterilised in pure liquid phenol (carbolic) or pure lysol (rinsing in sterile saline before use) or in hot oil. It is important to remember that rubber tubing should not be allowed to kink; free access of boiling water or steam to all parts of the lumen is essential for proper sterilisation. The loose glass beads and the closed glass-bead filter should, when possible, be sterilised in an autoclave. The loose beads, after washing, should be poured into a boiling tube; the tube should be closed with a plug of cotton wool, and the whole autoclaved; alternatively, a small screw-capped bottle may be used to contain the beads during autoclaving. If an autoclave is not available, pour the beads into the boiling tube and fill with citrate solution, close the tube with a muslin or gauze and immerse in boiling water for 20–30 minutes. Then remove the tube from the bath, ease the plug of gauze, drain out the citrate solution and pour the beads directly into the bottle of blood. The closed glass-bead filter, if no autoclave is available, may be sterilised in boiling water.

APPENDIX C

Methods of Continuous Drip Blood Transfusion and Intravenous Infusion

The Army or the Medical Research Council blood transfusion apparatus can be used for these purposes but, when giving blood, the bottle of either equipment should be gently shaken every twenty minutes, since the blood corpuscles tend to sediment. For prolonged transfusions, the Marriott-Kekwick apparatus, shown opposite, is more convenient; in this the blood is constantly stirred by a stream of oxygen bubbles. The apparatus, apart from the painted reservoir hanger, may be sterilised by autoclaving or boiling. During sterilisation, the two screw clips must be open. After sterilisation, the clips should be closed and dry sterile cotton wool should be packed into the two filters. An essential part of the apparatus (not shown in the illustration) is a filter of nickel wire gauze occupying the bottom of the reservoir. When the apparatus is in use, the reservoir, filled with blood, is suspended 3½ ft. above the patient. Clip B is then opened for long enough to allow the blood to run through the tubing and expel all air in it. The cannula is then inserted into a vein, preferably one just above the wrist or ankle. Clip B is loosened to permit the desired flow of blood, usually 40 drops per minute. The oxygen is turned on to deliver 40 bubbles a minute into the reservoir. Throughout a drip transfusion, the drip bulb must be frequently observed and Clip B adjusted if the flow is tending to slow down. On no account must the flow be allowed to stop, as, if it does, clotting will occur in the vein and cannula. If the fluid level in the drip bulb rises so as to foul the dripper, Clip B should be closed and Clip A opened for a few seconds to allow the level to fall; then Clip A should again be closed and Clip B re-opened. The Marriott-Kekwick apparatus may also be used for continuous drip infusion of saline or glucose, but the bubbling of oxygen is then unnecessary.



Marriott-Kekwick apparatus

APPENDIX D

The Reconstitution and Administration of Dried Serum or Plasma

(1) Dried Human Serum

Dried serum is a very stable product and is specially valuable when long storage under difficult conditions is envisaged. The serum is separated from blood which has been allowed to clot. It is bacteriologically filtered, and dried from the frozen state. It differs from plasma in the absence of fibrinogen. It has the advantage that it can be given in concentrated form, which has proved beneficial in cases of shock, especially burn shock. The serum can be given to recipients of any group.

Storage.

Keep as cool as possible and in a *dark* place.

Reconstitution.

The 12 oz. medical flat in which it is issued contains the solids from 200 cc. of serum. The serum is reconstituted by adding sterile distilled water, *i.e.*, B.P. distilled water filtered and autoclaved immediately after distillation.

For a twice normal concentration 100 cc. distilled water is added.

For a normal concentration 200 cc.

The levels to which the bottle should be filled to obtain these concentrations are usually indicated on the side of the label.

Solution, if the bottle is gently agitated, occurs as follows:—

Twice normal concentration in about 20 minutes.

Normal concentration in about 10 minutes.

Solution can be speeded up by placing the bottle in a bowl of warm water (not more than 40° C.) and rocking occasionally.

Solutions containing 14 per cent. and 7 per cent. of protein are thus available.

Dose.

Reconstituted serum can be used as an alternative to blood or liquid plasma. Twice normal concentration is recommended in conditions such as burn shock. Normal concentration, for cases where hæmorrhage has occurred and "shock" is present, with dehydration.

Experience has shown that 400 cc. (2 bottles) of serum is a suitable dose, though more may be required according to the severity of the case.

Administration.

Reconstituted serum can be administered by gravity, by means of an ordinary funnel intravenous-infusion apparatus with 4 ft. of tubing and a dripper, using a transfusion needle. Run in a little normal saline before the reconstituted serum. Allow at least 10–15 minutes to give each bottle of serum, whether normal or concentrated. Finally, run in a few cc. of normal saline, to wash in the serum remaining in the tubing.

An alternative method is to keep a transfusion bottle containing 400 cc. of sterile distilled water and 2 bottles of dried serum as a "unit." The appropriate amount of distilled water is added from the transfusion bottle to the two bottles of dried serum under sterile conditions. The resulting solution is returned to the transfusion bottle and administered with the ordinary transfusion apparatus. If a small needle is used it may be necessary to apply a slight positive pressure to the transfusion bottle by means of a suitable bulb.

DRIED SERUM AFTER IT HAS BEEN RECONSTITUTED SHOULD BE USED WITHOUT DELAY. IT SHOULD NOT BE STORED AWAY FOR FUTURE USE.

(2) Dried Human Citrate Plasma

The stability of this product is similar to that of dried serum. The citrate plasma is separated from blood which is mixed with a citrate diluent. It is bacteriologically filtered, and dried from the frozen state. The method of reconstitution and of administration is similar to that described for dried serum. Dried plasma is readily soluble. The protein concentration is about 5 per cent.

DRIED PLASMA AFTER IT HAS BEEN RECONSTITUTED SHOULD BE USED WITHOUT DELAY.
IT SHOULD NOT BE STORED AWAY FOR FUTURE USE.

APPENDIX E**Administration of Oxygen with the B.L.B. Apparatus**

This apparatus, described by Boothby, Lovelace, and Bulbulian, consists of a mask and a connecting device which joins the mask to a reservoir breathing bag (Fig. 1).

The Mask.—Two types of interchangeable rubber masks have been designed: (a) a nasal type which leaves the mouth free, and (b) an oro-nasal type which meets the requirements of cases in which adequate breathing through the nose is impossible. All normal adults can be fitted with one or other of the two sizes, small and large, of each of these two types. The nasal mask is provided with two hollow tubes which pass on each side of the mouth and unite over the lower part of the chin into a single tube. These tubes are in open communication with the rubber bag at all times through the connecting device. The mask is held in position on the face with an adjustable rubber strap, which is placed above or below the ears according to the comfort of the patient. Slight adjustments to the shape of the mask may be made by bending the malleable strips. A small hole is provided at the base of the nasal mask for the insertion, when required, of a gastric or a duodenal tube.

The Connecting Device.—On the side of the metal connecting device (Fig. 2) is an expiratory valve with a spring under slight tension, which permits the escape of any excess of expired air above that just sufficient to distend the bag, without causing any appreciable resistance to expiration. On the other side of the connecting device is an inlet connected with the oxygen cylinder; the oxygen enters through this inlet and is delivered through a tube into the lower part of the rubber bag. The upper part of the connecting device is provided with an air-regulating mechanism which consists of three small holes or ports, over which is mounted a rotating sleeve with three similar ports, one or more of which may be brought into operation by turning the sleeve. If desired, all the ports may be closed.

Reservoir Breathing Bag.—The rubber bag, which is similar to a football bladder, has a capacity of about 700 cc. When the apparatus is in use with all the ports closed, the first part of the expired air passes from the mask through the connecting device into the rubber bag, where it is mixed with the incoming oxygen. When the bag becomes distended, the slight pressure then produced permits the excess of expired air to escape through the expiratory valve. On inspiration the expiratory valve closes and the oxygen and expired air pass from the bag through the connecting device to the mask. By adjustment of the air-regulating mechanism different amounts of atmospheric air are mixed with oxygen in the inhalation apparatus. If concen-

trations of 80-90 per cent. of oxygen are required in the alveolar air, the apparatus must be used with all the ports closed. The flow of oxygen should be adjusted so that the bag does not collapse completely before the end of inspiration, for under these conditions the patient obtains all his inspired air from the bag. If lower concentrations of oxygen are required, one or more ports are uncovered and the patient breathes from the bag and the atmosphere.

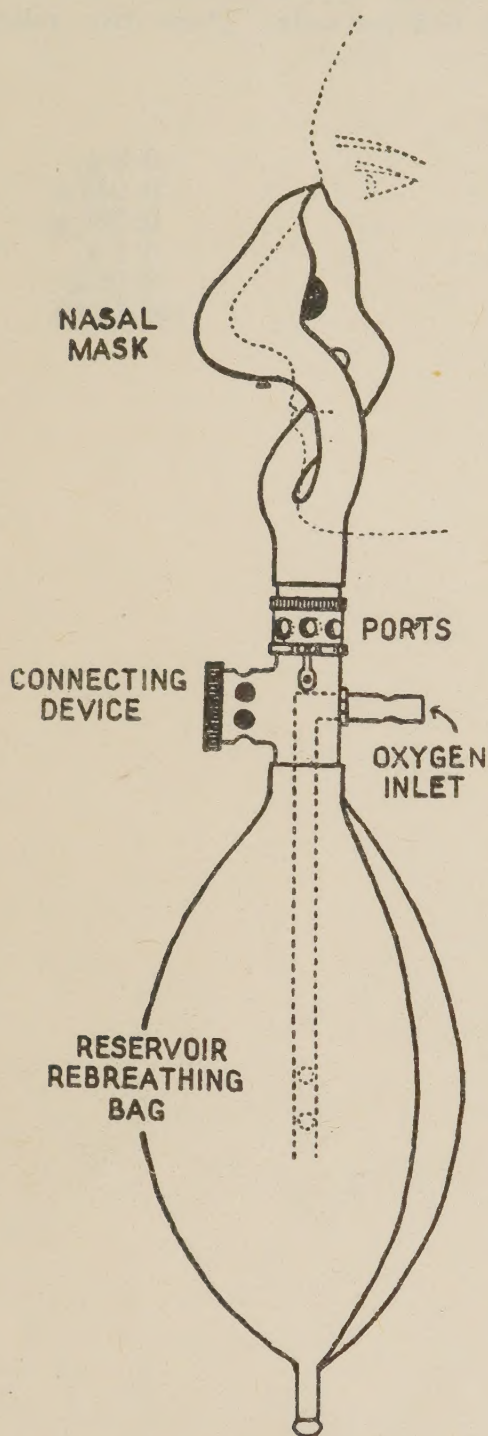


FIG. 1. The B.L.B. inhalation apparatus.

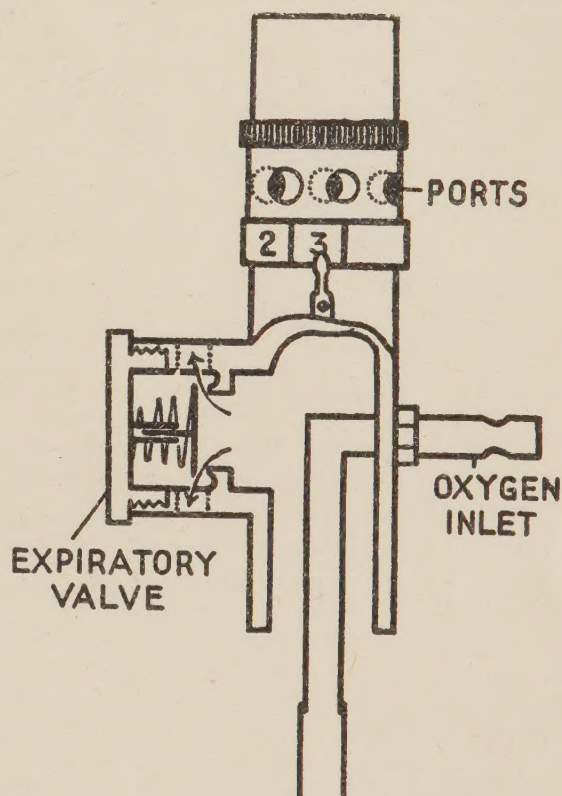


FIG. 2. The connecting device.

Table to show effect of alterations in flow of oxygen and of opening or shutting ports upon concentration of oxygen in alveolar air.

Flow of Oxygen (litres per min.)	Ports open	Oxygen in alveolar air (%)	Carbon dioxide in bag (%)	Flow of Oxygen (litres per min.)	Ports open	Oxygen in alveolar air (%)	Carbon dioxide in bag (%)
3	3	46	2.04	6	0	87	1.42
4	3	56	1.51	7	0	90	0.99
5	2	69	1.22	8	0	91	0.39
6	2	76	0.89				

For details see *Oxygen Administration; Indications, Methods and Types of Apparatus*. Ministry of Health Emergency Medical Service Memorandum No. 5. London (H.M. Stationery Office), 1940.

APPENDIX F

Composition of Solutions

ISOTONIC SALINE AND GLUCOSE

Isotonic saline = 0·9 per cent. Isotonic glucose = 5 per cent. These two solutions are usually administered as a mixture of equal parts.

RINGER-LOCKE SOLUTION (B.P.C.) :

Sodium chloride	..	..	..	..	..	..	0·9 g.
Potassium chloride	..	..	..	..	..	..	0·042 g.
Calcium chloride	..	..	..	..	..	..	0·024 g.
Dextrose (glucose)	..	..	..	..	..	..	0·1 g.
Sodium bicarbonate	..	..	..	..	..	..	0·05 g.
Water to	..	..	..	..	..	..	100·00 cc.

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